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INDIVIDUAL DIFFERENCES IN WORKING MEMORY CAPACITY AND THE RECALL OF PREDICTED ELEMENTS IN THE TEXT

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ABSTRACT

This study investigates the relationship between reading ability, working memory capacity, and readers' use and recall of the mechanism of Prediction. Reading ability was measured by free recall and by comprehension questions, and working memory capacity was assessed by the Reading Span Test (Daneman & Carpenter, 1980). Twelve Brazilian speakers of Portuguese read texts containing the mechanism of Prediction and were asked to verbalize their thoughts while reading. An analysis of the verbal protocols indicates that better and weaker readers, also high and low span respectively, showed a different behavior when recalling the information from the texts. Better readers tended to recall both the predictive signal and all the predicted elements correctly, and could also recall more propositions from each text. Weaker readers, on the other hand, tended to simply disregard the predictive signal and recall only some of the predicted elements, and to recall less information than better readers.

Leda Tomitch

INTRODUCTION

One of the most influential studies in the area of working memory capacity was that by Daneman and Carpenter (1980). Much of the research in this area has evolved from Daneman and Carpenter's work and has used, with little modifications, their Reading Span Test as a measure of working memory capacity, investigating how it correlates with a number of other cognitive skills including reading comprehension. Significant correlations have been obtained between the Reading Span Test and standardized measures of reading comprehension ability such

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as the Verbal Scholastic Aptitude Test- VSAT (Daneman & Carpenter, 1980; Turner & Engle, 1989) and the Nelson-Denny reading test (Masson & Miller, 1983; Baddeley, Logie, Nimmo-Smith & Brereton, 1985; Turner & Engle, 1989).

Reading Span has also been shown to correlate to a fairly great extent with a number of specific aspects of reading comprehension ability such as recalling information (Tomitch, 1996), answering comprehension questions (Tomitch, 1996), making inferences (Masson & Miller, 1983; Daneman & Green, 1986; Whitney, Ritchie & Clark, 1991; and Singer, Andrusiak, Reisdorf & Black, 1992), processing complex syntactic structures (King & Just, 1991; and MacDonald, Just & Carpenter, 1992) and resolving lexical ambiguities (Daneman & Carpenter, 1983; and Miyake, Just & Carpenter, 1994).

The present study is an expansion on Tomitch (1996) and has as its main objective to investigate the relationship between reading ability, working memory capacity, and readers' use and recall of the text organizational aspect of Prediction (Tadros, 1985). Prediction, as described by Tadros, involves a pair with two members: the predictive member and the predicted member. The predictive member carries signals which imply that a Prediction has been set up ('There are **two types** of ....) and the predicted member contains the realization of that Prediction (**One type**.....**The other type**...). The main assumption in the present study is that once the better reader spots a predictive signal s/he knows what kind of incoming information s/he should look for to fulfil the tacit commitment of the writer, thus putting less burden on working memory and being able to construct a more solid framework of the text's content which will help subsequent retrieval of that information.

The basis for this assumption comes from the following findings in text structure research: first, better readers are more capable of identifying the superordinate information in a text and of forming hierarchical clusters (van Dijk, 1980; Meyer, Brandt & Bluth, 1980; McGee, 1982). In a study about structural awareness of good and poor ninth-grade readers, Meyer et al (1980) found

that skilled readers tended to follow the same top-level pattern as the author to organize their recall whereas less skilled readers did not and tended to list ideas as if they were equally important. McGee (1982) found the same pattern of results with fifth-grade readers. Second, readers who employ a structure strategy recall more information from the text than those who do not (Meyer, Brandt & Bluth, 1980; McGee, 1982; Taylor & Beach, 1984; Carrell, 1985, 1992; Richgels, McGee, Lomax & Sheard, 1987). Third, structure aware readers recall more information from a normal or well organized passage than from a scrambled or badly organized one (Taylor & Samuels, 1983; Richgels, Lomax & Sheard, 1987). And finally, readers who use a structure strategy are more capable of identifying 'intruded information' which was actually not stated in the text (Meyer, Brandt & Bluth, 1980) or which is not compatible with the structure (Hiebert, Englert & Brennan, 1983).

On the basis of the research cited above it seems reasonable to hypothesize that the better readers in this study, also shown to have a larger working memory capacity in Tomitch (1996), will be more likely to perceive and report any distortion in the prediction pair than weaker readers.

Based on the rationale presented above, the present study investigates the following hypotheses:

1) Better readers, who are also higher span, are better able to recall elements explicitly predicted in the text.
2) Better readers, who are also higher span, are better able to notice distortions in terms of the text organizing mechanism of Prediction, i.e. better readers are also more able to perceive when the text fails to completely fulfil the expectations set up by the writer in the predictive member of the Prediction pair.

THEORETICAL FRAMEWORK

Individual Differences in Working Memory Capacity

The relationship between reading span and reading ability, measured by free recall and answers to questions about important information in the text, has been investigated by Tomitch (1996). In that study it was found that readers who recalled more propositions from a text and who were also able to answer more comprehension questions about the text, were also those with higher scores on the Reading Span Test (RST), i.e. better readers were also those with higher working memory capacity. The study showed that scores on the RST correlated significantly with the recall on two texts organized in terms of Problem/Solution ('Complete Problem/Solution'- r=.77, p=.003; and 'no solution'- r=.70, p=.01). Tomitch (1996) also reports the results of a second experiment where it is shown that there is a relationship between reading ability, working memory capacity and readers' awareness and use of a conventional pattern of text organization, namely, Problem/Solution (Hoey, 1979). The present study tries to expand on Tomitch (1996) and investigates whether there is also a relationship between working memory capacity and the use of another text organizational aspect- Prediction (Tadros, 1985).

Among the studies which have investigated the ability to make inferences we find Masson and Miller (1983), Daneman and Green (1986), Whitney, Ritchie and Clark (1991) and Singer, Andrusiak, Reisdorf and Black (1992). Masson and Miller (1983) found a strong correlation between Reading Span and readers' capacity to infer ideas not explicitly stated in the text and which thus depended on the integration of information given in different parts of the text. Daneman and Green (1986) found that readers with higher spans were more able to use contextual cues to infer the meaning of a novel word in a text. Whitney, Ritchie and Clark (1991) found that working memory capacity as measured by the Reading Span Test correlated with the

type of inferences readers made while processing difficult narrative texts. Singer, Andrusiak, Reisdorf and Black (1992) observed that an individual's ability to provide bridging inferences in contexts such as 'The spy quickly threw his report in the fire. The ashes floated up the chimney', was related to his/her working memory capacity, especially when the two sentences were separated by intervening text.

A few studies have investigated the processing of complex syntactic structures: King and Just (1991) and MacDonald, Just and Carpenter (1992). King and Just (1991) observed that an individual's ability to process complex syntactic structures such as center-embedded relative clauses was related to his/her working memory capacity, with higher span individuals performing better than lower span individuals on recall and comprehension tests. MacDonald, Just and Carpenter (1992) obtained support for a model of syntactic parsing called 'The Capacity Constrained Parsing Model' which tries to explain how working memory capacity can influence the processing of syntactic ambiguities in garden-path sentences such as 'The soldiers warned about the dangers...'. Their model predicts that both high and low span readers initially construct multiple representations (main verb and relative clause) and that the preferred representation (syntactically simpler, pragmatically more plausible, or more frequently encountered) is maintained in a higher level of activation than the unpreferred interpretation. However, low span readers cannot maintain both representations active while processing the rest of the sentence and have to abandon one of them (unpreferred) before the disambiguating information comes in the sentence, whereas high span readers keep both interpretations active. The model predicts that if the ambiguity is resolved with the preferred interpretation, both high and low span readers encounter no difficulties to comprehend the sentence. However, if the unpreferred interpretation is necessary for disambiguating the sentence, then low span readers tend to make more errors than high span readers, since they no longer have the unpreferred resolution active in working memory.

The resolution of lexical ambiguity has been investigated by Daneman and Carpenter (1983) and Miyake, Just and Carpenter (1994). Daneman and Carpenter (1983) observed that readers with smaller spans were less able to detect inconsistencies in sentences like 'He found a bat that was very large and brown and was flying back and forth in the gloomy room', where the previous context primed one meaning of the homonym (bat- baseball stick) but the target sentence gave an inconsistent disambiguation (bat- animal). It was even more difficult for smaller span readers to resolve the ambiguity when a sentence boundary intervened between the inconsistent disambiguation and the word to be reinterpreted as in 'There is a sewer near our home. He makes terrific suits'.

Using the same theoretical construct as that for the syntactic parsing model presented above, Miyake, Just and Carpenter (1994) obtained support for a model for the resolution of lexical ambiguity- 'The Capacity-Constrained Model of Lexical Ambiguity Resolution'. The model proposes that when a lexical ambiguity is encountered in a text, multiple representations are initially constructed, but higher span readers are more likely to maintain multiple representations until the disambiguating information is encountered.

The reading span measure has also been shown to be sensitive to task demands and to individual differences in prior knowledge. Fincher-Kiefer, Post, Greene and Voss (1988) found that working memory capacity is constrained by the processing demands required by a certain task. They asked individuals with higher and lower knowledge in a given domain to read domain-related and neutral passages. They found that domain-related material led to greater processing demands upon individuals with lower knowledge than upon individuals with higher knowledge, but only when subjects were required to recall the contents of the sentences besides their final words.

The study of individual differences in working memory capacity gave rise to a theory called 'Capacity Constrained Comprehension', proposed by Just and Carpenter (1992). The basic

premise of the theory is that comprehension processes are constrained by working memory capacity, with high span individuals performing better than low span individuals in language tasks. Individual differences in working memory capacity are then explained in terms of 'total capacity' and also in terms of 'processing efficiency'. According to Just and Carpenter (1992), 'both storage and processing are fueled by the same commodity: activation' (p. 123). The total capacity explanation posits that individuals vary in the amount of activation they have available in working memory for storage and processing. The processing efficiency explanation posits that some individuals have more efficient mental processes than others. According to Just and Carpenter, 'the two explanations are mutually compatible' (p.125), although, as they observe, the results of the studies they have carried out are better explained in terms of the total capacity account. Their reasoning is that differences in processing efficiency should occur independently of the total demand of the task, but the finding they have obtained is that when the comprehension task is easy, high and low span readers exhibit about the same performance, no significant differences are observed; whereas when the task is demanding, the differences between the two groups are 'large and systematic'.

Most studies on individual differences in working memory capacity have dealt with short stretches of discourse. Most of them have investigated processing at the sentence level (e.g. Turner & Engle, 1989; King & Just, 1991; MacDonald, Just & Carpenter, 1992; Miyake, Just & Carpenter, 1994) or at the paragraph level (e.g. Daneman & Carpenter, 1980, 1983; Fincher-Kiefer, Post, Greene & Voss, 1988; Yuill, Oakhill & Parkin, 1989; Singer, Andrusiak, Reisdorf & Black, 1992). Very few studies have dealt with longer texts (Masson & Miller, 1983; Daneman & Green, 1986 and Whitney, Ritchie & Clark, 1991). A considerable lack of research was found with longer and naturally occurring texts. Little research in working memory capacity has been carried out from a process-oriented perspective (Whitney, Ritchie & Clark, 1991; Tomitch, 1996). The present study is in the same line of research on working memory capacity as that by

Whitney, Ritchie and Clark (1991) and Tomitch (1996). The data is analyzed from a 'cognitive control perspective', the main interest being on how high and low span readers deal with information in the text when the overall structure is complete and when it is distorted.

Prediction as a text organizing mechanism

According to Tadros (1985), a difference must be made between Prediction and anticipation. In her use of the terms, Prediction involves signals in the text that commit the writer to fulfil an expectation; whereas anticipation does not involve predictive signals and the reader can only "anticipate" or "guess" what is going to come next in the text.

Tadros describes six categories of Prediction: enumeration, advance labeling, reporting, recapitulation, hypotheticality and question. This researcher chose to investigate the category of 'enumeration' (see Tadros, 1985 for a complete description of the six categories).

As suggested by Tadros, enumeration is a type of Prediction in which the writer commits himself/herself to enumerate. Regularly, enumeration involves the specification of more than one element in the predicted member. The predictive member of the pair contains a numeral (exact such as 'two', 'three' or inexact such as 'several', 'a number of') and an enumerable which includes 'sub-technical' nouns (e.g. 'functions', 'advantages') and 'discourse self-reference nouns' (e.g. 'examples', 'definitions'). The nouns which belong to the group of enumerables indicate that their referents will be in the text and thus do not include open-set nouns (e.g. computers, surgeries) which already have referents in the real world.

In the present study, it is hypothesized that better readers will be more prone to perceive when one of the elements of the predicted member is missing and to report the distortion.

METHOD

Participants

As previously mentioned, this study is an expansion on Tomitch (1996). Thus, the same subjects who participated in Tomitch (1996), participated in this study. They were twelve Brazilian native speakers of Portuguese, six better readers and six weaker readers[1], all undergraduate students taking regular courses at a federal university in the south of Brazil. Tomitch (1996) revealed that reading ability correlated significantly with working memory capacity, i.e. the better readers were also those with a higher reading span and the weaker readers were also those with a lower span[2].

Materials

All texts used in this study were written in the subjects' mother tongue- Portuguese. The whole experiment was carried out in Portuguese. In order to investigate the recall of the organizing mechanism of Prediction, when the complete structure is maintained, a text called "Sopro de beleza (Puff of beauty)" (Revista **Veja**, 1992) was used. As mentioned before, the Prediction pair consists of a predictive member which sets out an expectation to be fulfilled and of a predicted member which fulfils that expectation. The text used here contains three paragraphs and the Prediction pair is located in the last paragraph. The first paragraph introduces a new liposuction

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[1] In Tomitch (1996) subjects took two reading ability tests- free recall and answers to questions about important information in the text- and were later separated into two groups: better and weaker readers, according to the scores obtained in these two measures of reading ability. Readers with scores 50.25 or above were classified, for the purpose of this research, as 'better readers'. Readers with scores 36.4 or below were classified as 'weaker readers'. Better readers overall mean in the two measures was 61.14, whereas weaker readers' overall mean was 28.93. Results from the T-test showed that differences between the mean scores of better and weaker readers are statistically significant (Student T=6.43, df=10, p=.00007).

[2] The Reading Span Test consisted of 60 unrelated sentences, ranging from 13 to 17 words in length. Each sentence was typed in the center of a 14x22 cm card. The 60 sentences were arranged in three sets of two sentences, three sets of three, three sets of four, three sets of five and three sets of six sentences. The end of each set was indicated by a blank card. Each subject was instructed to read each sentence aloud trying to comprehend it, memorizing the last word of each sentence. Immediately after the subject finished reading a sentence, another card was placed by the researcher on top of the first and the subject began reading the next sentence. When the blank card appeared, the subject had to try to recall the last words of all sentences in that set, exactly in the same order they had been presented. When subjects failed all three sets at two subsequent levels, the test was terminated. The measure of the subject's reading span was the level at which he/she was correct on at least two sets. Half credit was given for passing one set at a certain level (Masson and Miller, 1983). In Tomitch (1996) better readers' scores (3.58) were higher than weaker readers' (2.41).

surgery with ultrasound which is supposed to have a major advantage over the traditional liposuction practice: it provokes a minimum loss of blood. The second paragraph gives a general description of the new surgery; and the last paragraph, which contains the Prediction pair, describes the new surgery in greater detail. The predictive member contains a numeral- 'three'- and an enumerable- 'steps' as follows: 'The new surgery is developed in **three steps**'. The predicted member of the Prediction pair contains the three items which fulfil the expectation as follows: '**First** the surgeon gives an injection with distilled water, sodium bicarbonate and anesthetics... **Next**, an ultrasound canula is introduced which provokes the burst of the fat cells only. **Last**, the region where the ultrasound was applied is pressed with a roll for the liquid fat to be expelled through the incision'. The Prediction pair is immediately followed by a favorable evaluation of the new surgery- 'The loss of blood is six times lesser than in the traditional liposuction'. In the present study, the numeral plus the enumerable in the predictive member will be called 'predictive signal', and the elements in the predicted member which fulfil the Prediction will be called 'predicted items'.

For the investigation on distorted Prediction, a text entitled "O cerco a Michelangelo (The siege to Michelangelo)" (Revista **Veja**, 1992) was used. The text contains three paragraphs and, as it was the case with the complete Prediction text, the Prediction pair is located in the last paragraph. The first paragraph presents the problem posed by the Michelangelo virus which, according to the text, could destroy all computer files on the sixth of March. The second paragraph defines computer viruses, elaborates specifically on the problem presented and introduces the solution in general terms ('Most people took the necessary precautions...'). The last paragraph elaborates on the anti-virus vaccines which are given as a solution to the presented problem. Again, the predictive member of the Prediction pair contains a numeral- 'three'- and an enumerable- 'types'- as follows: 'There are at least three types of vaccination programs against the computer virus'. Then, breaking expectations, the predicted member describes only two types of vaccination

programs, as follows: '**one of them** looks for the virus tracking each one of the filed programs, the invader is found and exterminated. **A second type** only localizes the clandestine and the user has to make use of another specific program to do away with the micro-invader'. The distortion in this text was the omission of the third element in the predicted member of the pair, the third type of anti-virus vaccine- 'and a third type prevents the virus from entering the machine'. The Prediction pair is immediately followed by negative evaluation about anti-virus vaccines- 'The problem about all types of vaccines is their high price. The Norton vaccine, against 700 viruses, costs the equivalent to 200 dollars in Brazil'.

The reasoning behind the methodology used in this study- distortion of one of the predicted items- is that if the reader perceives the distortion, i.e. if s/he explicitly says the text failed to mention the 'third type of anti-virus vaccine', it can only be because s/he had kept the predictive signal 'three' in working memory, which implies that s/he was using the text mechanism of Prediction to organize the flow of information in working memory.

Procedure

The whole experiment was carried out individually with each of the twelve subjects. Subjects read two texts: one where the complete structure of Prediction was maintained, and another where the Prediction structure was disrupted, as described above. While reading each of the two texts, subjects followed the pause protocol procedure, adapted from Cavalcanti (1987, 1989). It is a type of verbal report (Ericsson, & Simon, 1980) where subjects are given the whole text and asked to stop at points where they encounter a problem or something that calls their attention and give a report. In this study subjects were also asked to stop and give a report at the end of each paragraph (a red dot was placed at the end of the paragraph as a reminder) and after reading the whole text they were also asked to give a free recall of all they could remember from the text. Immediately after the recall they were asked a set of eight questions about their reading- a

retrospective interview (see Appendix). The comments made by the twelve subjects during the pause protocol procedure and during the retrospective interview were recorded and later literally transcribed. All the extracts from the transcription used in this paper were translated into English, since the whole experiment dealt with and was carried out in the subjects' mother tongue-Portuguese.

RESULTS

Hypothesis 1: Better readers, who are also higher span, are better able to recall elements explicitly predicted in the text.

In terms of better readers, three subjects recalled both the predictive signal and the predicted items correctly (S2/S4/S5):

S2: (comment made during recall of the paragraph containing Prediction) ...Then in the last paragraph it says that there are three steps... first they give an injection... distilled water and sodium bicarbonate and **analgesics**... to make the place swell where... where there's an excess of fat... then they put the ultrasound... ... it breaks this fat... and afterwards it goes out.

(comment made during recall of the whole text) It is divided into three steps ... the first is an injection... sodium bicarbonate... distilled water... and **analgesics** are introduced ... and then afterwards the ultrasound is introduced where by means of waves the ultrasound breaks ... the fat cells... they open... become liquid.. then they use a cylinder to press... then the fat goes out...

S4: (comment made during recall of the paragraph containing Prediction) It is saying that this surgery is developed in three steps: the first a solution with a bunch of things is injected in the region where there's an excess of fat, to make it swell to facilitate the surgery .. ... In the second, they put the device that will bombard... **the laser beam**, and then it will bombard the fat cells. And in the third, a cylinder is put on top of the region, which will take out the excess of fat in liquid form...

(comment made during recall of the whole text)... This surgery is developed in three steps: the first makes an edema in the region which has an excess of fat... putting a liquid inside... ... in the second, the device which will bombard is

put... ... **the laser beam** and ... **not laser beam... the ultrasound** ...then it breaks the fat cells and these cells become liquid and go out ... through the incision and after that... they roll ... not after that... a cylinder is rolled for these cells to go out through the incision...

S5: (comment made during recall of the paragraph containing Prediction) ... this liposuction with ultrasound is ... developed in three steps. First, they inject distilled water... sodium and an anesthetic in the region with ...fat... to make this region swell ... in a second step, they ... make the incision and introduce an ultrasound canula where it emits the high frequency waves ... in a frequency ... that... makes the adipose... cells ... break and become liquid and then in the third step, they roll a cylinder... on top of the region and it makes possible for this liquid... quantity... liquid fat to be expelled through the incision.

An interesting aspect regarding memory occurred in S2's and S4's recall above. S4 insisted on mentioning laser beam instead of ultrasound, but then during recall of the whole text she corrected herself. In fact, the two devices can be used in surgery, but the difference between them may not be very clear for a layman, which could easily lead to an interchange between the two during retrieval from memory.

S2 showed a similar behavior when trying to retrieve 'anesthetics', except that she did not correct herself. She recalled 'analgesics' both during recall of the last paragraph and also of the whole text. In this case, besides belonging into the same 'drugs' schema, 'anesthetics' and 'analgesics' also share sound characteristics. According to Smyth, Collins, Morris and Levy (1994) the likelihood of a word substitution increases when the two words share both meaning and sound features.

There might be one difference between the recall of S2 and S4, S2 did not correct herself, therefore we can not be sure whether the change occurred during encoding, i.e. she internalized 'analgesics' instead of 'anesthetics' at the very moment she perceived the word on the page; or during retrieval, i.e. she encoded 'anesthetics', but during retrieval, she got mixed up and recalled 'analgesics'. As for S4, it seems more likely that she encoded 'ultrasound', since she corrected herself during recall of the whole text.

The phenomenon observed above is described in the literature of memory as 'slips of the tongue'. Smyth, Collins, Morris and Levy (1994) define this phenomenon as 'involuntary and unintentional speech errors' (p. 186), where the speaker intends to say one word and actually produces another. According to these authors, the reasons which lead to word substitutions may be the following: similarity in terms of meaning and/or sound, frequency of use of the word and also the communicative context in which the selection of the word occurs.

Another better reader (S6) did recall the predictive signal correctly- 'three steps'- but in the recall of the predicted items she showed comprehension problems in step number two- she did not mention the ultrasound and misunderstood that the fat cells became liquid because they were pierced:

S6: (comment made during recall of the paragraph containing Prediction) ... it is developed in three steps: first, the surgeon gives a ... needle with distilled water, sodium bicarbonate and anesthetics... ... then he... he makes an incision only in the fat cells and... then... **since they became liquid because of this incision they ... are expelled** ... (comment made during recall of the whole text) ... This surgery is developed in three steps... first the surgeon ... he introduces a needle only in the fat cells... ... **afterwards the fat cells are pierced... incised... they become liquid forming a kind of material since they were incised**...

In fact, S6 made a pause during her reading of the paragraph containing Prediction, she asked to reread the paragraph, and during the retrospective interview, she said she found the text 'more or less' difficult and gave it a 3 on the scale 1-very easy/ 6-very difficult; she also said that what had made the text difficult was the fact that 'it talked about the techniques of the surgery, which demanded more attention'. She also gave the text a 3 on the familiarity scale (1-totally familiar/ 6-totally unfamiliar) and commented that she had never heard of the new surgery. S6's reported difficulties with the text were confirmed by her recall protocol: she had the second worst score during paragraph recall and also during whole text recall.

Another better reader did not mention the predictive signal, but referred to the structure of the paragraph using the general term 'description' (S1). He had got confused when describing the third step, but then seemed to have made up for that during recall of the whole text:

S1: (comment made during recall of the paragraph containing Prediction) There is a new description of the method, but now in a more... detailed way... Well, first, a series of injections are given to swell... ... this injection is given which is... distilled water, sodium bicarbonate and then anesthesia... an incision is made and in this incision, an ultrasound canula is introduced... and then in the case in point the ultrasound is switched on, bombards the place and then a cylinder is rolled... ... **I don't know if it is the cylinder which leaves the fat in liquid form or if the cylinder is simply used to let the fat out**.

(comment made during recall of the whole text) ... A series of injections are given... ... and then the device is put **which breaks the fat** and after that a cylinder is rolled which takes the fat out...

It is interesting to note that S1 was able to correct himself without any further access to the text, since whole text recall was done immediately after recall of the last paragraph. According to Gambrell, Koskinen and Kapinus (1991), free recall involves 'verbal reconstruction of text acquired information' (p. 356) and leads readers to elaborate and organize the information which has just been read by focusing their attention on the text as a whole. What possibly happened to S1 was that during verbalization of the whole text, he recapitulated the information which had been presented and by putting all this information together he was able to elucidate doubts he probably had.

And the last better reader (S3) did not mention the predictive signal, but like S1 above, she referred to the structure of the paragraph ('they explain how...'). From her recall of the predicted items, it is not clear whether she understood the second step as she made no reference to the use of the ultrasound:

S3: (comment made during recall of the paragraph containing Prediction) Here they explain how the surgery is developed. First they inject water and a bunch of other things there which I don't know their names... I mean... I know... but memorizing like this is difficult... And afterwards... to make the region swell... when **the fat cells explode**... they roll a kind of cylinder there... for the fat to go out in liquid form.

(comment made during recall of the whole text) ... Here they talk about the surgery, an incision is made where there is more fat... they inject some substances ... **and the fat cells explode and change into liquid**... then they roll a cylinder and take the fat out in liquid form.

S3 did refer to the fact that the fat cells explode, but from her recall it is not clear whether they explode because of the ultrasound or because of the drugs which make them swell. In fact, during the retrospective interview, S3 said that the text didn't flow very well, she gave it a 4 on the difficulty scale and another 4 on the familiarity scale. She commented that what had made the text difficult was the technical vocabulary- medical terms. Like S6, mentioned above, S3's reported difficulties were also confirmed by her recall protocol: she had the lowest score on the recall of the paragraph containing Prediction (50% lower than four other better readers) and the lowest score on whole text recall.

As to the weaker readers, only one subject (S7) did not mention the predictive signal. However, like the two better readers mentioned before (S1/S3), S7 referred to the structure of the paragraph ('they explain in detail how...'). She was the only weaker reader who recalled all three predicted items correctly:

S7: (comment made during recall of the paragraph containing Prediction) Here they explain in detail how the liposuction with ultrasound is developed... they use distilled water to make the region with fat swell... and an anesthetic... and then they use this device... by means of ultrasound... which transforms the fat into liquid... and then they roll a cylinder on top... for the liquid to come down to the incision... to be expelled from the body...

(comment made during recall of the whole text) ... In the third paragraph, they say they use anesthetic... distilled water... to make the place swell... and after having used the ultrasound... when the fat became liquid.... they use a cylinder ... on top... for the fat to be expelled through the incision.

The other five subjects recalled the predictive signal correctly, but were not able to recall all the predicted items correctly (S8/S9/S10/S11/S12):

S8: (comment made during recall of the paragraph containing Prediction) Here the three steps of ... liposuction with ultrasound are mentioned. First they put sodium bicarbonate and anesthetics ... and then... they put a ... it must be a

pipe... in the incision and then ... and that **they widen the skin a little to make it easier**... and then... they roll a cylinder so that this material is expelled.

S9: (comment made during recall of the paragraph containing Prediction) This surgery is made in several steps... an injection with distilled water and anesthetics is given... and then **a cylinder is rolled to unmake the fat cells... and this canula is introduced... to take the excess of fat out**.

(comment made during recall of the whole text) It is developed in three steps... the first an injection with... distilled water and ... anesthetics is given... **a cylinder is rolled, it dilutes the liquid... this ultrasound canula, it takes the excess of fat out... the fragments which remained... then it becomes liquid** ...

S10: (comment made during recall of the paragraph containing Prediction) And this surgery with ultrasound... it is... through an equipment... they spot the fat and the fat is bombarded. And with that... the fat is undone... **with the incision it disappears**.

(comment made during recall of the whole text) This last part... it is developed in three steps. The first step is... they give injections where the person has fat, so that it swells... and then they put the device... and the fat cells are blown... and then **the device which makes the incision... it changes into liquid**.

S11: (comment made during recall of the paragraph containing Prediction) ... It is developed in three steps... the surgeon gives an injection of bicarbonate and anesthetic, this is to make the ... adipose tissue... swell, then with the ultrasound ... with... I don't know with what he... he ... with the ultrasound **it spreads**, only the fat cells and after that then with a cylinder... **they roll a cylinder and it becomes liquid**.

S12: (comment made during recall of the paragraph containing Prediction) This type of lipoaspiration is developed in three steps... then he puts the three steps... **I'm not going to say because I don't remember**...

(comment made during recall of the whole text) ...And this type of surgery... is developed in three steps... **I know an injection with distilled water is given... that I remember**...

A summary of the results for the recall of better and weaker readers in relation to the predictive signal and the predicted items is presented in Table 1:

TABLE 1- Better vs. weaker readers' recall of the predictive signal and the predicted items- Complete Prediction text

	BETTER READERS						WEAKER READERS					
	1	2	3	4	5	6	7	8	9	10	11	12
PREDICTIVE SIGNAL		X		X	X	X		X	X	X	X	X
PREDICTED ITEM 1	X	X	X	X	X	X	X	X	X	X	X	X
PREDICTED ITEM 2	X	X		X	X		X			X		
PREDICTED ITEM 3	X	X	X	X	X		X	X				

Results show that the first hypothesis was partially confirmed. Although both better and weaker readers tended to recall the predictive signal- 'three steps'- there was a difference between them in terms of the recall of the three predicted items. Whereas four better readers recalled all three predicted items correctly, only one weaker reader (S7) was able to do so.

As mentioned before, the Prediction pair described the liposuction surgery with ultrasound in reasonably great detail. The enumerable in the predictive signal- 'steps'- implied that a 'sequence' of events would be described in a given order. The signals which preceded each of the three predicted items- 'first', 'next' and 'last' confirm this Prediction. Results presented above suggest that better readers recognized and were more able to follow the sequence to organize recall of the predicted items: whereas five of them reproduced the same sequence as that used by the author (S1/S2/S3/S4/S5), only three weaker readers did so (S7/S8/S11). Furthermore, from the five better readers who reproduced the sequence, four of them correctly recalled all the predicted items (S1/S2/S4/S5), whereas only one of the three weaker readers who reproduced the sequence was able to do so (S7).

Regarding the number of propositions recalled for the paragraph containing Prediction, there was also a statistically significant difference between the two groups (Student T= 2.47, df= 10,

p= 0.03), i.e. better readers recalled significantly more propositions (55.14%) than weaker readers (30.05%). The analysis of the recall protocols, as presented before, revealed that most weaker readers had problems in understanding the individual propositions in the predicted items of the Prediction pair, which described the new surgery. In addition, four of the weaker readers rated the text as moderately difficult and pointed to 'vocabulary' as the source of difficulty; three weaker readers also rated the subject of the text as moderately unfamiliar.

According to Just and Carpenter (1992), processing a sequence of sentences, within the capacity limitations of working memory, is possible because of some mechanisms which reduce the demands for processing and storage. Context is given by Just and Carpenter as the mechanism which can facilitate processing. Among the mechanisms which reduce the demands for storage they include the following: only the most recent propositions remain activated as well as only the most relevant aspects of prior knowledge; each new word or phrase tends to be interpreted as soon as it is encountered; after higher level structures have been built, lower level representations may be deactivated. It is possible that the unfamiliarity with the vocabulary and subject of the text affected weaker readers' performance in this text. First, they might not have been able to benefit from the context provided in the text which could have helped them interpret the stream of input, i.e. they probably failed to activate the relevant 'concepts, relations and schemas' (Just & Carpenter, 1992) which could help them process the incoming sentences; second, they might not have been able to interpret each incoming word or phrase immediately, having to wait for more input to do so; third, since they could not access referential meaning immediately, forming higher level structures had to be postponed until more input arrived, leading to a need for storage of more surface information. Failure in the mechanisms described above might have overwhelmed working memory by increasing the demands for processing and storage to an unmanageable level, leading to a decrease in performance.

HYPOTHESIS 2

Better readers, who are also higher span, are better able to notice distortions in terms of the text organizing mechanism of Prediction, i.e. better readers are also more able to perceive when the text fails to completely fulfil the expectations set up by the writer in the predictive member of the Prediction pair.

In terms of better readers, only one of the six subjects explicitly mentioned that there was a distortion, in a comment made during the recall of the whole text. However, his protocol shows that he became confused and tried to make up for the text by adding a third type of vaccine from memory (S1):

S1: There are three types... the text only describes two... I don't know whether the third type is the one which destroys... one which finds and destroys, another which only finds ... and another which destroys... there are three...

Since S1 had kept the numeral 'three' from the predictive signal and could only retrieve two predicted items, he seemed to have drawn upon two alternatives to solve the impasse: first, 'it is a failure in the text itself' ('the text only describes two'...), but he seemed confused and did not sustain this affirmation and drew upon another alternative- 'It's a failure in my memory' ('I don't know whether'...) and thus made up his hypothesis ('...the third type is the one which destroys'), a probable inference from the two types mentioned. Guided by this hypothesis, he started the search in his memory for the three items: retrieved the first type ('one which finds and destroys'), retrieved the second type ('another which only finds'), and then retrieved his 'educated guess' as actually being mentioned in the text ('and another which destroys'), thus opting for the second alternative- 'my memory may have deceived me' ('there are three'...).

S1 engaged in what Bartlett (1932, in Ashcraft, 1994) describes as 'an effort after meaning' or what is called today 'reconstructive memory' (Ashcraft, 1994; Anderson, 1995) or 'reconstructive changes' (Searleman & Herrmann, 1994), which is defined as 'the tendency in recall or recognition to include ideas or elements that were inferred or related to the original stimulus but

were not part of the original stimulus' (Ashcraft, 1994:681). Searleman and Herrmann point out that it may often be very difficult to determine exactly where a particular inference occurred, at encoding or retrieval. However, in the case presented above, it seems likely that it occurred during retrieval. One reason which points to this interpretation is that during immediate recall of the paragraph containing the distorted Prediction, S1 recalled the predictive signal 'three' and the two predicted items effectively mentioned, without adding the third missing item from memory nor referring to the distortion:

S1: ... He describes three types of vaccines against the virus, sold in Brazil... One looks for the virus and destroys the virus... There is another type that only looks for the virus, then one has to use another program to destroy the virus... and then the price is also discussed...

It was only during whole text recall that he became confused and added the third missing item.

Three other better readers did not make any explicit comments about the distortion but replaced the numeral 'three' in the predictive signal with 'several' (S4/S5), or with 'two' (S3/S4), or ignored the predictive signal and mentioned the predicted items only (S3); but all three subjects recalled correctly the two predicted items effectively mentioned:

S3: (comment made during recall of the paragraph containing Prediction) There is a type of vaccine... which you put... in a diskette and it already finds and destroys ... and the other vaccine you put and it finds the virus, but you would have to bring another program in ... to destroy that type of virus.

(comment made during recall of the whole text) ...there are two types... one of the vaccines... finds and destroys the virus... the other vaccine ... it finds and you have to use another program against that virus... to terminate with it...

S4:(comment made during recall of the paragraph containing Prediction) ... these vaccines have several forms of action... one of them detects the invader, the virus in this case and... terminates with it... another type only detects the invader but another program is needed to terminate with this invader...

S5: (comment made during recall of the paragraph containing Prediction) ...there are several types of vaccines... one finds and destroys the virus and another only finds it and one has to resort to other ... methods... to destroy the virus...

Like S1 mentioned above, these three better readers were also involved in some kind of reconstruction during retrieval. For them, the predicted items had a 'retroactive interference' in their memory for the predictive signal. Ashcraft (1994) describes 'retroactive interference' as a type of interference in which 'newer material interferes backward in time with your memory for older items' (p.154).

One better reader recalled the predictive signal but not the predicted items (S2):

S2: (comment made during recall of the paragraph containing Prediction) ...There are three types... which are expensive...

Only one of the better readers kept the predictive signal- 'three types'- and recalled the two predicted items mentioned in the text without making any comments about the distortion (S6):

S6: (comment made during recall of the paragraph containing Prediction) There are at least three types of vaccines... one vaccine ... it tracks the whole... filed program... looking for the virus and when it finds it destroys it. Another vaccine only finds the place where the virus is and the user has to use another type of vaccine to... do away with it... (comment made during recall of the whole text) ...there are at least three types and that ... one tracks the whole... the whole program looking for the virus and when it finds it... destroys it, another only finds the virus and the user has to... resort to another device to destroy...

One possible explanation for S6's recall is that she might erroneously have taken 'at least' in the predictive signal as an indication that the author would need to provide 'a number of' examples and not necessarily the 'three'. In fact, she was the only reader who recalled the expression 'at least'; she included it in both paragraph recall and whole text recall.

In terms of the weaker readers, none of them made explicit comments about the distortion. One subject, however, replaced the numeral 'three' in the predictive signal with 'two' (S7):

S7: (comment made during recall of the paragraph containing Prediction) This one is talking about the anti-virus vaccines... that there are two... one tracks the whole program and is able to terminate with the virus... and the other only finds it and ... another person has to look for another program ... which exterminates it.

Only one of the other five weaker readers recalled the predicted items correctly. She made up for the text by replacing the predictive signal- 'three types'- with a demonstrative- 'these'- plus an open set noun- 'vaccines' (S11):

S11: (comment made during recall of the paragraph containing Prediction) ... these vaccines ... from these vaccines one finds the invader, they are made with magnetic diskettes and ... they find the invader and destroy, others only find and the user has to ... has to find an specific mean to ... eliminate it...

(comment made during recall of the whole text) ... and these vaccines are magnetic diskettes which... introduced in the computer they find the virus and destroy and others... simply find and the user... finds... specific means to eliminate it...

Three other weaker readers only made reference to the existence of anti-virus vaccines and recalled general information, without actually describing the two types mentioned (S8/S9/S12):

S8: (comment made during recall of the paragraph containing Prediction) ... The second here talks about... **the anti-virus vaccines, which are expensive**....

S9: (comment made during recall of the paragraph containing Prediction) Then some ...users ... they got a... diskette which is... **the anti-virus... then it eliminates all the existent viruses in the computer**... it cleans... it doesn't let this virus damage what is written, what is recorded.

(comment made during recall of the whole text) ... To fight that... magnetic tapes were recorded and ... **users make that for various types of virus**...

S12: (comment made during recall of the paragraph containing Prediction) Oh My God... let me see... A diskette is used... and this diskette... **there is a vaccine against the virus, which is the anti-virus... and it is introduced and eliminated, the virus**... the only thing is that it's very expensive...

(comment made during recall of the whole text) ...There is an **anti-virus vaccine which is introduced in the computer... and it goes tracking, taking out ... and it goes searching and eliminates the virus**...

Finally, the other weaker reader recalled the predictive signal- 'three types', but was not able to recall the two predicted items effectively mentioned (S10):

S10: (comment made during recall of the paragraph containing Prediction) ...there are three types of vaccines against the virus... one which the person adopts... and the virus is found inside the computer and destroyed... and another

type **that the viruses can be killed through diskettes**. Now, I think it is the virus itself which is the story programmer...

S10 recalled the first type 'apparently' correctly, apparently because when he tried to recall the second type, he was not able to and he brought in information ('...another type that the viruses can be killed through diskettes') implying that this was a characteristic peculiar to the second type of vaccine. This suggests that he did not understand a basic premise in relation to all anti-virus vaccines, at least as described in the text: '... all of them sold in the form of magnetic diskettes for computers'. Actually, S10 did not refer to the mode of action of the second type of anti-virus vaccine ('it only localizes the clandestine and the user has to make use of another specific program to do away with the micro-invader').

A summary of the results related to the recall of the predictive signal and the predicted items is shown in Table 2.

TABLE 2- Better vs. weaker readers' recall of the predictive signal and the predicted items- Distorted Prediction text

	BETTER READERS						WEAKER READERS					
	1	2	3	4	5	6	7	8	9	10	11	12
PREDICTIVE SIGNAL (L)	X	X				X				X		
PREDICTIVE SIGNAL (R)			X	X	X		X					
OPEN SET NOUN (VACCINE)								X	X		X	X
PREDICTED ITEM 1	X		X	X	X	X	X	X	X	X	X	X
PREDICTED ITEM 2	X		X	X	X	X	X				X	
PREDICTED ITEM 3 (M)	X											

(L)= literal recall of the predictive signal

(R)= replacement of the predictive signal (M)= attempt to provide from memory

Results indicate that the second hypothesis was not confirmed. In fact, neither better nor weaker readers explicitly reported the distortion. However, all better readers referred to the predictive signal, either by recalling exactly what was mentioned in the text- 'three types' (three better readers) or by replacing the predictive signal to suit the predicted items (three better readers), whereas only two weaker readers did so. Furthermore, five of the six better readers recalled the two predicted items effectively mentioned in the text, whereas only two weaker readers were able to do so.

The fact that four of the six better readers 'reconstructed' the Prediction mechanism indicates that it had some importance in the organization of information in memory and suggests that they were using the mechanism of Prediction to organize the flow of information during reading. A possible explanation for the fact that they did not report the distortion is that although they might have attended to the numeral 'three', working memory became so busy processing the incoming input that the numeral was just displaced with the subsequent flow of processing.

An explanation for such results may be that the type of Prediction used in this study organized the text at the micro-level and was not crucial to the understanding of the text as a whole. Actually, at the macro level, the text was organized in terms of Problem/Solution with the problem being 'the Michelangelo virus which would attack on the sixth of March and could destroy all files in the computer'; 'the anti-virus vaccines' were given by the text as a solution to the problem. Therefore, the specification of the 'types of vaccines' with their modes of action would then be a response to the problem at the macro level. It could be that better readers were more concerned with identifying the solution given by the text and concentrated their attention on the open set noun- 'vaccines' (related to the predictive signal)- and their modes of action (predicted items), thus not giving full attention to the numeral 'three', since it was not so important in terms of the macrostructure of the text. A possible evidence for this comes from the pattern of recall shown by better readers: they tended to replace the enumerable in the predictive

signal to match the predicted items effectively mentioned and tended to recall the two predicted items.

The pattern of results shown by weaker readers may indicate that they might have gone through a difference process: they tended to disregard the predictive signal and pick up one of the predicted items and use it as general information for the topic of the paragraph. This may indicate that they were not using the mechanism of Prediction or if they were attempting to use it they were so affected by task demands that much of the information was displaced while reading, what led them to maintain only a sense of what was going on in the paragraph.

The recall protocols suggest that weaker readers (also lower span) were more affected by the task of maintaining global coherence and processing the paragraph containing the distorted Prediction. As already mentioned before, whereas five of the six higher span readers correctly recalled the two predicted items effectively mentioned, only two lower span readers did so. Actually, weaker readers retained much less information from the paragraph containing Prediction (Student T= 3.03, df= 10, p= .01) and also from the whole text (Student T= 4.8, df= 10, p= .0007) than better readers. During the retrospective interview, except for one weaker reader (S8) who considered the text as very easy and totally familiar, all others reported having difficulties with the subject of the text. As opposed to text 1 (complete Prediction), this time the reported difficulties were not specifically related to vocabulary but to an unfamiliarity with the subject.

As already observed, context is a mechanism which can reduce processing demands (Just & Carpenter, 1992). According to Just and Carpenter, the stored context provides for the pre-activation of relevant 'concepts, relations and schemas' necessary for comprehension. Weaker readers might have benefited less from the context provided in the text, since the subject was unfamiliar, thus overwhelming working memory with storage and processing of the succeeding sentences, leading to a detriment in performance.

The fact that lower span readers recalled less information than higher span readers does suggest that they were more affected by task demands, as suggested above. In order to comprehend the text, they were probably faced with the trade off between storing and computing relationships and some partial results may have been displaced or 'forgotten' (Just and Carpenter, 1992). This is further supported by the fact that there was a strong correlation between working memory span and whole text recall for the two texts: complete Prediction ($r = .61$; $p = .03$) and distorted Prediction ($r = .65$; $p = .02$), i.e. the number of propositions recalled from each of the two texts was directly related to working memory capacity.

GENERAL DISCUSSION

Regarding the text mechanism of Prediction, neither better nor weaker readers reported the distortion of the predicted items. However, better readers tended to reconstruct the Prediction pair so that predictive and predicted items would still match, whereas weaker readers tended to ignore the predictive signal and use one of the predicted items as the topic of the paragraph. This might indicate that better readers are more aware of the mechanism or at least more able to use it during their reading to organize the input information. This is reinforced by the fact that during recall of the paragraph containing complete Prediction, better readers tended to follow the same sequence as the author's to organize their recall of the predicted items, whereas weaker readers tended not to be able to do so. The fact that better readers did not report the distortion may be due to its role in the text. It organized the text at the micro-level, not affecting the discourse as a whole.

The results in the present study revealed differences in the performance of better (higher span) and weaker (lower span) readers while processing the complete and the distorted texts. As observed in the review of the literature, individual differences in working memory capacity can be explained by two hypotheses: total capacity and processing efficiency (Just & Carpenter,

1992). The total capacity hypothesis posits that individuals vary in the amount of activation they have available for storage and processing, therefore high span readers exhibit a better performance in language tasks because they would have more activation to support the two functions. The processing efficiency explanation posits that individuals vary in the efficiency of their mental processes, therefore high span readers' better performance in language tasks would be due to the fact that their mental processes do not consume all the available capacity in working memory and thus leave more capacity for storing the intermediate products. The results obtained in this study revealed differences between the two groups in terms of use of text structure during reading, and also in terms of comprehension and retention of the information in the texts, being congruent with the processing efficiency explanation. However, it does not rule out the possibility that high span readers' better performance was also due to more activation available to support processing and storage.

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